PART 1

CHARACTERIZATION OF THE SYNDROME

CHAPTER 1 INTRODUCTION

During the 1970s declining vigour and death of eucalypts on grazing properties on the Northern Tablelands of New South Wales became a subject of general concern. Not only were existing trees in all age classes declining, but there was also very little recruitment of new seedlings.

Some of the tree loss was due to the natural death of ageing trees or the deliberate removal of trees which obstructed proposed developments or were required for timber. However, most tree deaths were associated with a premature loss of vigour, seemingly in response to unusual environmental stress.

This premature decline of trees, which became known as "rural dieback" (Kile, 1981), was not confined to the Northern Tablelands. The syndrome was also prevalent in the Central and Southern Tablelands of N.S.W. as well as other scattered areas throughout Australia. Reports (Old et al, 1981) indicated that the incidence of rural dieback had greatly increased between 1975 and 1980 throughout Australia.

Rural dieback of eucalypts is far from fully understood (Boyd, 1965; Mackay, 1978; Ministerial Working Group, 1979; Kile et al, 1980; Wylie and Yule, 1980; Old et al, 1981).

There is a need to understand eucalypt dieback so that remedial action can be taken to minimize its impact. This study was initiated in order to attempt to describe the nature and extent of rural dieback on the Northern Tablelands. Since rural dieback appears to be a complex disorder the investigation was designed to be preliminary and exploratory rather than definitive.

1.1 Tree declines - a brief overview

Harper (1977) noted that the age structure of most temperate forests so far examined reflects the prominence of destruction of trees in tree population dynamics. Though much of this destruction is related to disasters, such as fire or felling by humans, the importance of epidemic diseases, insect outbreaks and unusual climatic stress should not be underestimated.

During the last century there has been increasing concern about unexpected or "unusual" tree mortality in many parts of the world (Houston, 1979). There are two trends which would increase the prevalence of epidemic tree diseases and other tree declines.

Firstly, as a result of the greatly increased movement of people and goods the spread of pathogens and pests of trees to susceptible tree populations has accelerated. For example, the beech scale insect, **Cryptococcus fagisuga**, (Houston, 1979) which was introduced into North America in the 1890s became the prime agent involved in predisposing American beech (**Fagus grandifolia**) to beech bark disease caused by the fungus, **Nectria coccinea var faginata** Lohman, Watson and Ayers. Other examples of pathogens and pests spread by man include: Gypsy moth (**Lymantria dispar**) which was introduced into oak forests in the United States (Campbell and Sloan, 1977); Dutch elm disease (Gibbs, 1978) which was spread to America in the 1920s and back to Europe in a more virulent form in the 1960s; and Phytophthora cinnamomi which is associated with large-scale mortality of a wide range of trees both temperate and tropical (Zentmyer, 1979).

Secondly, in many areas environmental changes induced by man have favoured the onset of tree disease or pest outbreaks. Subtle changes include shifts in the species composition and age structure of forests following logging operations; more drastic changes have resulted from agricultural and industrial development. Prominent examples include tree deaths resulting from photochemical pollution, especially in California (Kozlowski, 1979), and tree deaths attributed to acid precipitation particularly in Central Europe (Pearce, 1982).

In addition a significant proportion of tree decline appears to be unrelated to human activities. For example, periodic infestations of spruce budworm (Morris, 1963) occur in natural stands of balsam fir; extensive investigations found no evidence to suggest that man's influence has made the incidence of infestations greater. Also, some non-specific tree disorders appear to be related to climatic extremes, e.g. dieback of white ash in North America appears to result from stress imposed by unusually dry conditions rendering trees susceptible to attack by canker causing fungi (Ross, 1966).

It should be noted that there are many tree declines that have not been satisfactorally explained. Some of these, for example oak decline, involve complexes of agents that appear to contribute to the stressing of trees; the stressed trees become susceptible to attack by weak secondary pathogens which would otherwise be innocuous (Houston, 1973). Fink and von Braun (1978) have written an extensive review covering these diebacks.

1.2 Eucalypt dieback in Australia

The term "dieback", originally only refered to disorders in which plants die back from the tips (U.S.D.A., 1953). However, it is generally used as a loose term to describe all serious eucalypt crown disorders resulting from any cause (Marks and Idzak, 1976). Marks et al (1972) classified eucalypt dieback symptoms attributable to Phytophthora cinnamomi into acute and chronic types of injury. In cases of acute injury the entire crown wilts, leaves turn brown and the tree often dies while the leaves are still attached. Partial recovery may occur through epicormic shoots. These symptoms resemble acute drought damage (see Section 2.1). The chronic form of injury attributable to P. cinnamomi involves excessive leaf fall and thinning of crowns and resembles symptoms produced by a variety of disorders. Symptoms similar to this chronic crown deterioration may also result from fire, drought, nutrient deficiencies, various root pathogens, insect damage and other causes (Podger, 1976). Gradual crown deterioration also appears to be a part of the natural senescence

TABLE 1.2.1 CROWN DIEBACK SYNDROMES IN AUSTRALIAN FORESTS.

(A) Associated with insects.

Phasmatid defoliation Periodically affects large areas of ash type forests in south eastern Australia, but a wide range of trees in areas as far north as Queensland may also be affected.
[Ref: Readshaw (1965), Neumann, et al (1977), Wylie and Bevege (1981)]

Jarrah leaf-miner (Perthida glyhopa) Chiefly defoliates E.rudis in south western Australia. A large proportion of foliage is often consumed in successive seasons.
[Ref: Mazanec (1981)]

Psyllid outbreaks A number of psyllid species are subject to outbreak. Infestations often last several years and weakened trees surccumb to secondary infestations, e.g. by woodborers. Sometimes different species of psyllids and even other insects reach outbreak populations during the same period.
[Ref: Hopkins (1976), Wylie and Bevege (1981)]

Other insect outbreaks Some other insects may reach outbreak populations under certain conditions, e.g. a severe infestation of **Stathmorrhopa aphotista** (Lepidoptera: Geometridae) caused severe damage to about 1000 HA of forest in southern Tasmania; 2 years later few insects remained.
[Ref: Elliot, et al (1981)]

(B) Associated with fungal pathogens.

Phytophthora cinnamomi root rots P.cinnamomi appears to act as a primary pathogen in at least some susceptible plant communities. Direct fungal damage ranges from necrosis of fine roots to girdling of the main stem and major roots.
[Ref: Old (1979), also see Section 6.1.]

Armillaria luteobubalina root rot This fungus appears to be a primary cause of decline and death of a wide range of trees and understorey plants in mixed eucalypt forests in central Victoria. Symptoms usually include dieback of primary branches, crown thinning and production of epicormic shoots. Ultimately the foliage wilts and the tree dies. Death of saplings and shrubs may occur rapidly.
[Ref: Kile (1981b), Anon (1978)]

of ageing trees (Jacobs, 1955).

Forests

Until now most research concerned with eucalypt dieback has involved forests. Several discrete dieback problems of eucalypt forests have been recognized in Australia (Bird et al, 1975; Hopkins,1976). The best known of these problems concerns jarrah forests in Western Australia; it has been attributed to the root pathogen **P. cinnamomi** (Newhook and Podger, 1972), which is currently regarded as the most serious pathogen of eucalypts in Australia (Old, 1979).

P. cinnamomi is also believed to be responsible for some eucalypt dieback in Victorian and Tasmanian forests. However, there has been little reported damage in other states even though P. cinnamomi is a common soil isolate in eastern New South Wales and Queensland (Old, 1979).

The more important dieback syndromes of Australian forests are listed in Table 1.2.1; sources of further information about each syndrome are indicated. The etiology of most of these syndromes appears to be complex and not well understood (Podger, 1981 and Kile, 1981a).

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Table 1.2.1(continued)

Disorders attributed to foliage pathogens Severe damage to eucalypts caused by foliage pathogens occurs infrequently. A 4000 HA stand of **E.nitens** was severely defoliated by **Aulographina eucalypti** in Victoria in 1974. [Ref: Keane et al (1981)]

(C) Associated with drought/ microclimate.

Acute drought damage In severe droughts trees on sites prone to depletion of soil water may suddenly wilt, often the trees are killed outright. [See Sections 2.2, 9.2.]

Gully dieback This is an instance of dieback affected **E.obliqua** in a mixed forest in north-east Tasmania. The 1967 drought appeared to be the major stressing factor. Trees were also defoliated by **Uraba lugans**, with some subsequent damage by **Armillaria** spp. [Ref: Palzer (1981)]

High altitude dieback Affects mature **E.delegatensis** in the central highlands of Tasmania. The decline appears to be associated with dense regrowth of rainforest understorey plants. Experimental removal of the understorey using fire led to recovery of the test trees. [Ref: Ellis, et al (1980)]

(D) Complex syndromes.

The diseases discussed under the previous headings usually involve a number of contributing determinants besides the main factor listed. However, there are syndromes in which discussion in terms of a single stressing factor is misleading.

Regrowth dieback This affects **E.obliqua** and **E.regnans** in 30 - 100 year old stands in southern Tasmania. Affected trees are randomly distributed in stands and include all size and dominance classes. The symptoms involve a slow decline in crown condition, terminating in death. The disease appears to be associated with the incidence of a number of drought years in combination with defoliation by a chrysomelid beetle and possibly necrosis of fine roots by a Cylindrocarpon sp. **Armillaria** spp. also appear to be involved as secondary agents. [Ref: Jehne (1976), Podger et al (1980), Podger (1981)]

Rural areas

Authors commenting on rural dieback from a national (or state) perspective have usually stressed that no single agent is solely responsible for the mortality and morbidity of native trees (Wylie and Yule, 1979; Kile et al, 1980; Old et al, 1981; Pryor, 1981).

Pryor (1958, 1981) emphasised natural senescence of ageing trees as a major element in the tendency of rural eucalypts to become moribund and die. He also noted that tree decline is spasmodic: ageing trees become vulnerable during periods of excessive stress, for example during droughts, floods and insect outbreaks.

Kile et al (1980) noted that many factors contribute to the frequently moribund condition of rural trees and that these factors vary between regions. They cited several cases, such as salination of soils in North-West Victoria and a localized incidence of severe defoliation of river red gums (Eucalyptus camaldulensis) by possums, for which the causal agents responsible for the tree decline were readily identified. Nevertheless, they stressed that knowledge of causes of tree decline over extensive areas is far from complete.

Several accounts of rural dieback on the Northern Tablelands (Mackay, 1978; Anon, 1979; Ministerial Working Group, 1979) mention the prominence of defoliating insects in the syndrome and suggest that excessive defoliation by a number of species of native insects is probably the major immediate cause of tree mortality. However, only circumstantial evidence was available to support their conclusion and the authors agreed that the underlying reason for excessive insect defoliation is uncertain. A more thorough examination of the syndrome was clearly required. Such a study should also have some relevence to understanding dieback in other areas which are also utilized for pastoral production.

1.3 Scope of the study

The report is organized into 3 parts. Part 1 is concerned with:

(a) Characterizing the symptoms shown by declining eucalypts and designing a system for rapidly evaluating the vigour of eucalypts (Chapter 2).

(b) Characterizing spatial patterns of the incidence of dieback (Chapter 3). This involved: i) a broad-scale survey of the Northern Tablelands in order to determine which eucalypt species are most affected by dieback, the main areas involved, and what factors are regularly associated with dieback; and ii) a more intensive study of dieback on an individual property using multivariate statistics to access the relationships between site and tree factors and the vigour of trees.

(c) Monitoring changes in the vigour of selected trees (Chapter 4) in order to provide an indication of the development of dieback. Some trees were treated with insecticides and fungicides to investigate the contribution of foliage feeding insects and pythiaceous fungi to eucalypt dieback.

In Part 2 of the report the information gathered from these studies and other available sources is used to critically appraise the factors contributing to eucalypt dieback on the Northern Tablelands. Selected aspects, especially the role of Phytophthora cryptogea, were investigated experimentally.

Part 3 is concerned with a discussion of the possible underlying causes of the syndrome. Some recommendations for remedial action and further research are provided.

CHAPTER 2 SYMPTOMS OF EUCALYPT DIEBACK AND ASSESSMENT OF CROWN CONDITION

This chapter has two functions: (1) to characterize the symptoms of eucalypt dieback on the Northern Tablelands, and (2) to describe the development of a method for rapidly evaluating the vitality of trees. Such a method was considered essential for field work requiring assessment of the incidence and severity of dieback and monitoring changes in the vigour of trees. Assessment of crown condition was considered the most practical approach for estimating the vitality of trees. Development of the method of crown assessment required: i) information concerning normal variations in the crown condition of healthy eucalypts, and ii) information concerning the symptoms of crown deterioration evident on the Tablelands.

2.1 Crown condition in healthy eucalypts

Growth habits of eucalypts have been described in detail by Jacobs (1955). Hence only salient points will be noted here.

(1) The form of eucalypts changes during the course of growth. The following growth stages were defined by Jacobs (1955): seedling, sapling, pole, immature tree, mature tree, and overmature tree. A discrete pole stage is not as clearly marked in woodland eucalypts (in contrast to forest eucalypts), but the other growth stages can be clearly recognized. Amongst woodland eucalypts it is common for establishing saplings to die back

repeatedly and to resprout from lignotubers or stems; some of the saplings finally become established when growing conditions are suitable (see Section 11.1). In an otherwise vigorous stand of trees there are usually some older trees which show stageheadedness or other symptoms of crown deterioration. Inter-tree variations in crown shape also occur.

(2) Even amongst mature vigorous trees there is a continuous process of loss and replacement of limbs. Therefore, some dead limbs are usually present on all trees.

(3) Where trees grow close enough to interfere with each other some trees usually become dominant while other trees are suppressed. In an otherwise vigorous stand it is common for the crown condition of some suppressed trees to deteriorate; this deterioration often leads to the death of the individual trees.

(4) In eucalypts there are large variations in crown density both for the same tree over time, between trees of the same species growing in different locations and between different species. Usually flowering and seed production of a given tree vary between successive seasons. In years when there is heavy flowering the production of new foliage is limited. Leaves have a finite life span, e.g. 2 to 3 years in Eucalyptus blakelyi (Clark and Dallwitz, 1974). Often the ageing leaves senesce simultaneously during a particular season; so a significant portion of the crown may be suddenly lost, with a marked change in density, especially if there was little production of new leaves in the preceding season.

(5) Eucalypts can tolerate substantial defoliation without becoming irreparably damaged. Mechanisms to compensate for damage to the crown include: indeterminate shoot growth; accessory buds, which can replace the naked buds if they are damaged; and proventitious buds, which remain dormant beneath the bark but can be activated to produce new epicormic shoots if required. Most eucalypts also have lignotubers with dormant buds which can be activated if the aerial parts of the tree are destroyed. Reserves of starch and mineral nutrients in the sapwood also increase the capacity of eucalypts to withstand defoliation.

2.2 Crown symptoms associated with eucalypt dieback on the Northern Tablelands.

At the commencement of the project the typical symptoms of eucalypts exhibiting dieback on the Northern Tablelands involved general deterioration of the crown with foliage thinning and progressive twig and branch dieback. Declining trees were usually reproductively inactive. All size classes of trees were observed to be affected. Woodland trees situated in areas utilized for pasture production were those which most commonly showed decline. Insect induced defoliation was observed in most of the affected trees, but no particular insect was consistently responsible. Scolloping of leaves, chiefly by paropsine and scarab beetles, was the most prevalent form of insect-induced damage, but leaf-skeletonizing was also evident and sap-sucking also contributed to the general problem. Many insects, e.g.

most gall formers, severely infested individual trees but had a sporadic distribution. Table 2.2.1 lists the more common insects found to be involved in the defoliation of eucalypts.

Fungal shoot and leaf pathogens do not appear to be important as agents affecting eucalypts on the Northern Tablelands. However, local infestations of the leaf spotting fungus **Mycosphaerella cryptica** (identified by R.F. Park, Latrobe University) were noted on seedling regeneration of **E. blakelyi** in several locations in the Armidale -Wollomombi area and an unidentified **Mycospharella** spp. was also noted on **E. pauciflora** near Point Lookout (see Fig 3.0.1 for location). Dry weather prevalent during the study period probably restricted the activity of fungal foliage pathogens. Fungal damage to leaves wounded by insects was common and could be of importance. In particular, parts of leaves damaged by the probosci of leafhoppers are often the focal points of fungal colonization.

There were also localized infestations of mistletoes which probably also affected eucalypt survival in some areas (see Section 6.4).

Following general crown deterioration partial recovery in the form of bursts of epicormic shoot production usually took place after some months or in the next growing season. However, the epicormic growth was liable to deteriorate in a similar manner to the original crown. This cycle of decline -recovery -decline was often repeated several times (see Fig. 2.2.1). Usually the last leaves died and remained on the tree (see Fig.

Table 2.2.1 Some common insects contributing to defoliation of eucalypts on the Northern Tablelands.

Coleoptera	
Chrysomelidae	Paropis atomaria P. aegrota Paropsisterna beata Chrysophthata varicollis C. m-fuscum other Chrysophthata spp. Cadmus spp.
Scarabaeidae	Anoplognathus porosus (Christmas beetle) A. hirsutus Sericestis geminata
Curculionidae (weevils)	Gonipterus scutellatus several other weevils
Lagriidae	Lagria grandis
Lepidoptera	
Nolidae	Uraba lugens (gum leaf skeletonizer)
Limacodidae	Doratifera sp. (cupmoth)
Geometridae	Mnesampela privata
Psychidae	unknown spp. (case moth)
Xyloryctidae	(woodmoths)
various unidentified leaf-tiers	
Hymenoptera	
Pergidae (sawflies)	Perga sp.
Hemiptera	
Eurymelidae (leafhoppers)	Eurymelloides pulchras Eurymela sp.
Eriococcidae (scales)	Eriococcus coriaceus several other spp.
Psyllidae (lerps)	several spp.

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Fig 2.2.1 Typical symptoms of rural dieback. A **Eucalyptus nova-anglica** 6 km north-west of Armidale (9.9.79). The original crown has been replaced by epicormic shoots. The first generation of epicormic shoots has also mostly died off and been replaced by successive generations of epicormics.

Fig 2.2.2 A **Eucalyptus viminalis** with wilted epicormics, on the Old Inverell Rd. about 7 km west of Armidale (26.9.80).

2.2.2); often particular portions of the tree died in this manner while other parts of the tree remained intact. There was no consistent pattern in the order in which branches senesced. In trees that previously contained full crowns the lower (suppressed) branches often died back first, but sometimes upper branches were lost first, and sometimes one side of the tree. The time span over which decline occurred had not been systematically observed but appeared to vary from less than a year to many years. Landholders gave contrasting accounts of this time span: it appeared to vary between localities and for different species.

Variations from the common symptoms were sporadically observed in most common species, e.g. E. viminalis, E. caliginosa, E. nova-anglica, E. melliodora and E. pauciflora. In these cases trees wilted while still bearing a significant proportion of their leafy crown, and the brown leaves remained on the tree for weeks or months (see Fig. 2.2.3). Partial epicormic recovery sometimes followed, but often the tree died. These symptoms are similar to acute drought stress but were noted while drought conditions were not prevalent.

During the autumn of 1980, and at times during the following 3 years, the effects of drought on trees were evident over wide areas (see Section 3.5). As a consequence tree condition deteriorated in some areas hitherto unaffected by dieback. Some drought damage was evident in trees growing under a diversity of conditions, but acute drought effects were generally restricted to the vegetation on skeletal soil overlying coarse granite or

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Fig 2.2.3 A Eucalyptus melliodora showing sudden wilting of the crown (Univ. of New England campus, 5.10.80).

Fig 2.2.4 Acute drought damage affecting a stand of shrubby woodland during May 1980 (about 35 km west of Armidale; grid ref: 325 387). The wilted tree in the foreground is **Eucalyptus caleyi**.

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Fig 2.2.5 An oblique aerial photograph showing acute drought damage in the Bundarra Range (31.8.65). [Photo taken by J.B. Williams.]

Fig 2.2.6 Wilting of trees on a rocky knoll west of Uralla (1.4.81; grid ref: 427 142). The large tree is Eucalyptus youmanii, the small tree is Acacia implexa. The apparently vigorous saplings are also E. youmanii.

porphyry on hills mostly west of the Divide. The effects were similar to those observed during the 1965 drought (Cremer, 1966; Pook et al, 1966; Hoult, 1970; Pook, 1981). Moderate drought stress involved a reduction in crown density resulting from increased leaf fall (see Fig. 4.3.2), and splitting of the main trunk due to contraction, often accompanied by entry of wood-boring insects. Bleeding from kino veins usually followed in the recovery phase. Where drought stress was acute patches of the crown suddenly wilted and turned brown. In severe cases the entire crown was lost. In many cases the major branches died and a staghorn appearance remained; sometimes the entire trunk died and recovery was only from lignotubers. Drought damage was intensified by infestations of longicorn beetles which often completely girdled the tree. In sites where eucalypts were damaged by drought understory species were usually damaged as well. In some areas there was a complete browning-off of foliage of all vegetation giving the impression of a landscape recently burnt by a bushfire (see Figs. 2.2.4, 2.2.5 and 2.2.6).

2.3 Wood decay and root symptoms associated with eucalypt dieback.

Wood decay is common in eucalypts exhibiting symptoms of rural dieback. However, heart rots that do not affect the living wood are dominant; rotting of living sapwood is only occasionally evident. White sapwood rots were only noted in E. nova-anglica (rarely) and E. bridgesiana ssp. bridgesiana.

The sapwood rot of E. bridgesiana appeared to be associated with the fruiting bodies of an unidentified species of Osmoporus. This particular rot affected a large proportion of E. bridgesiana in areas just north of Armidale, especially in the area between Mt. Duval and Lake Dumaresq. The process of wood decay is discussed in more detail in Section 6.1. In most areas termites were common and had entered most trees. In one case a 5 cm diameter lignotuber of E. viminalis (from U.N.E. campus, October 1981) already contained termites. Structural damage to trees, resulting from past clearing activities, use of mechanical equipment or fires, also appeared to be associated with woodrots.

Only limited excavation of major tree roots was attempted. Most information about the condition of major roots was derived from examination of windblown trees (see Fig. 2.3.1) and trees which had been removed by bulldozers. Nothing is known about the condition of major roots beyond a depth of one metre.

There was significant mortality of major roots of most dieback affected eucalypts examined. However, all live trees examined had intact major roots and there was some apparent replacement of dead roots. No evidence of Armillaria rhizomorphs or fruiting bodies was observed among the eucalypts examined, but ramification of mycelia in the cambial region was observed in one recently killed E. viminalis (U.N.E. campus, October 1981). Unfortunately, isolation of the fungus onto V8 agar and Russell's agar (see Appendix B) failed.

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Fig 2.3.1 Exposed roots from a wind-blown Eucalyptus nova-anglica, near Sandy Creek about 60 km east of Armidale, October 1982. The predominance of shallow roots appears to be a typical feature of this species.

Examination of the condition of fine roots was carried out whenever possible when soil samples were taken from the bases of trees for the isolation of pythiaceous fungi (see Section 6.7). Living roots were white and pliable and could easily be distinguished from dead roots.

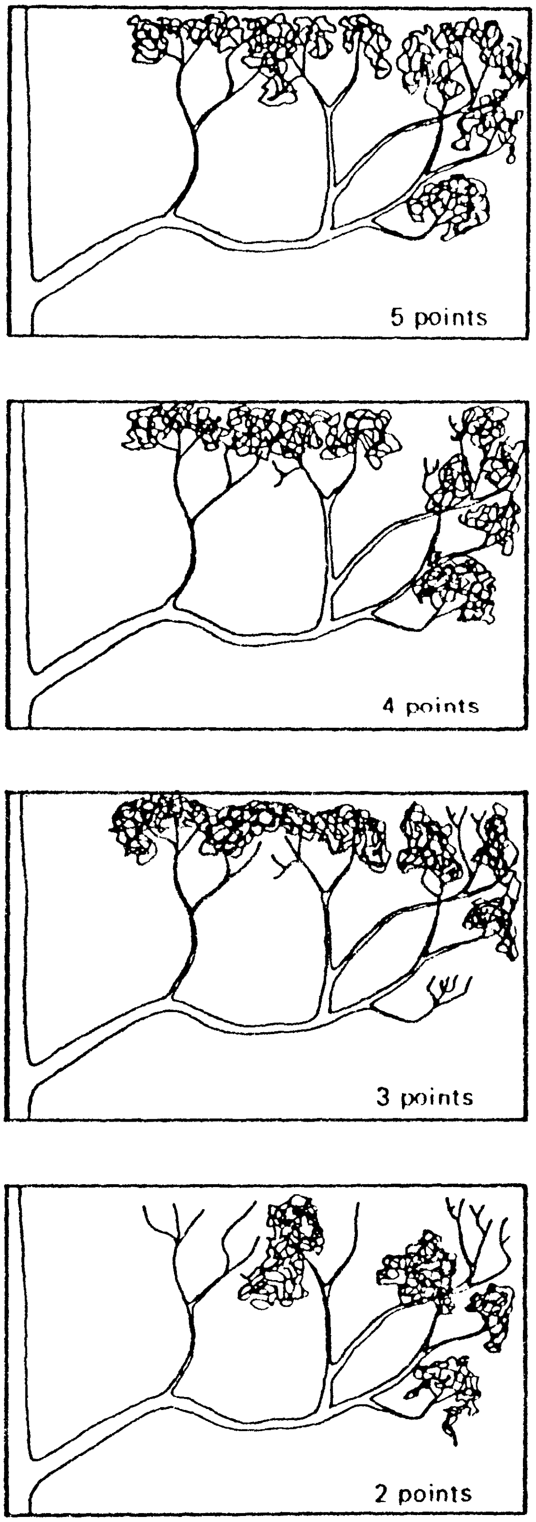
In addition, during December 1979 the fine roots (diameter less than 3 mm) were systematically examined in 6 trees at "Kiparra" and 3 trees at Eastwood State Forest (see Fig.3.0.1 for location). Areas of grass cover were avoided. At "Kiparra" the mortality of minor roots was high (i.e. about 50%) in all species examined (**E. melliodora, E. blakelyi** and **E. caliginosa**). At Eastwood the mortality of rootlets of each of the individuals of each of the three species (the same 3 species) was comparatively low (i.e. less than 25%), ectomycorrhizae were prominent and the rootlets extended into the decomposing litter above the actual soil. Vigour ratings (see Section 2.5) of the trees examined at both sites ranged between 4 and 6. The major differences in the soil environment between the two sites were that leaf litter was more abundant and total foliage cover was greater at Eastwood. Thus if the mortality of rootlets was related to dehydration, the differences in rootlet mortality between the two sites was as might be expected. Alternative explanations for rootlet mortality were carbohydrate starvation due to excessive grazing of foliage by insects (see Section 6.1) and direct damage by pathogens (see Section 5.2). By January the soil in most areas had dried out and hardened so that examination of roots was difficult.

E. nova-anglica rootlets examined at Newholme in August 1980 showed neglible mortality. The trees had apparently recovered to some extent during the preceding season and their was little sign of current defoliation. At other sites, including "Kiparra", rootlet mortality was also reduced compared to the previous year and most dead rootlets were partly decomposed indicating that the mortality was not recent. Since the condition of most of the trees that were not excessively moribund began to improve during this period (see Chapter 4) no further examinations of fine feeding roots were attempted.

2.4 Existing methods of crown assessment.

Systems for classifying the crowns of eucalypts have been developed in the past for a number of purposes.

Foresters have developed systems of crown assessment to facilitate prediction of tree growth in normal forest stands. For example Grimes (1978) developed a system for predicting diameter increment in spotted gum - ironbark forests using relative position of the crown, crown size, crown density, proportion of dead branches, and development of epicormic growth as predictive characters. Regression analysis confirmed that all these characters were associated with diameter increment. Using a pictorial key as a reference each character was separately rated on a point scale with arbitary boundaries between the categories (see Fig. 2.4.1). Thus the assesssment was open to subjective bias and field training was necessary to maximize



NIL

BRANCHLETS DEAD

SMALL GROWING
BRANCHES DEAD

MAIN GROWING
BRANCHES DEAD

Figure 2.4.1 Assessment of Dead Branches (After Grimes, 1978) consistency of assessment between different workers.

Arbitrary scales have also been used by workers attempting to assess the severity of eucalypt dieback. For example Cross (1979) used a five point scale in a field project designed to determine site factors associated with eucalypt dieback on Newholme property just north of Armidale. As with Grimes' scale the categories were defined by loose descriptions, e.g. "small branches dead, some epicormic growth but mainly the original canopy of mature foliage". Since only comparitive determinations were critical the project only required approximate assessment of crown condition and the simple subjective scale was probably adequate.

Hoult (1970) developed an 8 point scale of eucalypt vitality in order to assess the recovery of trees after the 1965 drought (see Table 2.4.2). This scale used the observation that branch dieback of eucalypts following droughting is progressive: with moderate stress causing only leaf loss, more intense stress causing death of twigs, and so on. The principle that most stresses induce progressive branch dieback facilitates construction of suitable scales, however the chronic nature of rural dieback, confounding recovery and deterioration, makes the scale itself unworkable for assessment of rural dieback.

Studies involving monitoring the course of a disease require more precise ways of determining tree vitality. Workers in the Victorian Forestry Commission investigating eucalypt dieback associated with Phytophthora cinnamomi (I. Smith, pers. comm.)

TABLE 2.4.1 HOULT'S TREE VITALITY SCALE.

0	Whole tree dead
1	Base of trunk alive
2	Lower trunk alive
3	Upper trunk alive
4	Lower branches alive
5	Upper branches alive
6	Small twigs only dead
7	Leaf fall, but no or very few twigs dead
8	No apparent die-back.

[Ref: Hoult (1970).]

have resorted to taking photographs of trees from fixed reference points in order to assess changes in tree condition. Aerial photography has also been used for monitoring the development of disease in forest stands. A technique for the assessment of regrowth dieback in Tasmania was developed (Myers, 1981) in which aerial photographs are taken on cloudy days to maximize the contrast between tree crowns and the understorey vegetation.

Photographs can also be used to produce standards for the comparison of trees. A set of ten reference photographs taken from below the canopy of E. obliqua trees with varying severity of regrowth dieback has been used to assess disease development (West and Podger, 1980). The assessments have quantitative significance since the reference standards were ranked to indicate the proportion of primary branches in the actively extending part of the tree that had died back from the branch terminus.

Other research workers have also developed techniques for assessing dieback quantitatively. The Forestry Commission of N.S.W. has used estimates of percent defoliation as the basis for determination of tree vitality (Nicholson and Clark, unpublished). Defoliation was estimated by considering the proportion of dead branches on the tree as well as using binoculars to assess leaf damage and leaf loss on the living branches. Their technique distinguished the original (primary) crown of mature leaves from the secondary crown derived from the epicormics that developed after substantial defoliation of the original crown. Both components of the crown were considered separately. The method appeared to achieve consistent results but the capacity of eucalypts to quickly replace lost leaves suggests that percent defoliation is probably not an ideal measure of tree vitality.

2.5 A system for measuring eucalypt dieback for the Northern Tablelands.

The system adopted for assessing mature trees involved classifying trees into categories on: (a) a tree vigour scale and (b) a foliage cover scale.

(a) Tree vigour scale

As discussed in section 2.2, the major symptom of eucalypt dieback in rural areas on the Northern Tablelands is a general deterioration of the crown. Following the practice of the CSIRO Division of Forest Research in Tasmania (see section 2.4 and West and Podger, 1980) an estimate of crown deterioration in terms of the reduction of actively growing branches was considered a significant measure of disease. In addition, the principle used in Hoult's scale, i.e. crown dieback following a major stress is usually progressive, was incorporated in the measure.

The scale contains 9 categories (see Table 2.5.1) with trees that are definitely dead rated 0 and apparently healthy trees rated 8. Categories 5 -7 (and to some extent category 4) were defined by the proportions of twigs on the primary crown which were apparently dead. Boundaries between these categories were

Table 2.5.1 Eucalypt vigour rating.
(modified from E.H. Hoult, 1970)

0. Dead (certain), heavy twig loss, bark splitting.

1. Completely defoliated with no live foliage, but tree relatively intact; possibility of sprouting new growth from branches or bole; often dead leaves remaining on tree.

2. Epicormic growth no higher than main trunk; no mature foliage.

3. Epicormic growth no higher than lower branches; no mature foliage.

4. Foliage predominately epicormic (usually no higher than upper branches) <u>or</u> greater than 75% of twigs on primary crown apparently dead.

5. Between 50-75% of twigs on primary crown apparently dead.

6. Between 25-50% of twigs on primary crown apparently dead.

7. Less than 25% of twigs apparently dead, but tree not completely healthy; substantial epicormic growth or defoliation; little reproductive activity.

8. Apparently healthy.

Table 2.5.2 Sapling vigour rating.

0. Apparently dead.

1. Greater than 75% of twigs on actively extending parts of crown apparently dead.

2. Between 50-75% of twigs on actively extending parts of crown apparently dead.

3. Between 25-50% of twigs on actively extending parts of crown apparently dead.

4. Less than 25% of extending twigs apparently dead, but substantial defoliation.

5. Apparently healthy.

chosen to accord with the principle (Large, 1966) that subjective estimations are perceived on a geometric scale rather than an arithmetic scale. A geometric scale is also more likely to have biological significance than an arithmetic scale. Categories 1 to 3 are similar to the same categories on Hoult's scale. The addition of category 0 allows the author to distinguish completely defoliated trees that may be capable of producing new growth from epicormics or lignotubers (category 1) from those that are definitely dead (category 0).

Trees are viewed from a standard distance, approximately equal to the height of the tree. Estimations of twig mortality are supported by spot checks of the proportion of dead twigs using binoculars. Rapid estimation of twig mortality and the attainment of consistency in results between two workers (A.I. Fleming and C. Nadolny) required some experience.

Initial experience with the measure indicated that the ratings generally accorded with subjective estimates of the relative condition of trees. However, some trees that had deteriorated many years ago but had not subsequently recovered, were given higher ratings than their condition warranted. (This was because they had lost the dead twigs that usually remained on recently deteriorated trees.) This anomaly was a primary reason for introducing the foliage cover scale as a supplementary measure.

(b) Crown foliage cover

Since the quantity of foliage is the main determinant of energy production by the tree, a measure of the quantity of foliage in relation to the size of the tree is biologically relevant. Ideally such a measure should relate the leaf area to the cross-sectional area of the trunk. In practise the estimation of this ratio is difficult. Firstly, perceived crown density varies with the width of the crown and, secondly, woodland trees usually have irregular crowns.

The use of a set of photographic standards to illustrate variations in crown foliage cover was considered inappropriate because of the diversity of crown structure in the eucalypt species involved in the study and the differences in foliage density of apparently vigorous eucalypts of the same species growing in different areas. Instead a set of standard diagrams was drawn to illustrate major variations in projected foliage cover. Five foliage density classes were distinguished. The diagrams were based on the silhouette of the skeleton of an E. melliodora tree of typical woodland form. A perfectly circular and continuous projected image was taken as the perfect crown and diagrams showing 6.25%, 12.5%, 25.0% and 50.0% projected foliage cover were drawn to illustrate the boundaries between the foliage classes (see Fig. 2.5.1). A diagram of 75% projected foliage cover was also included.

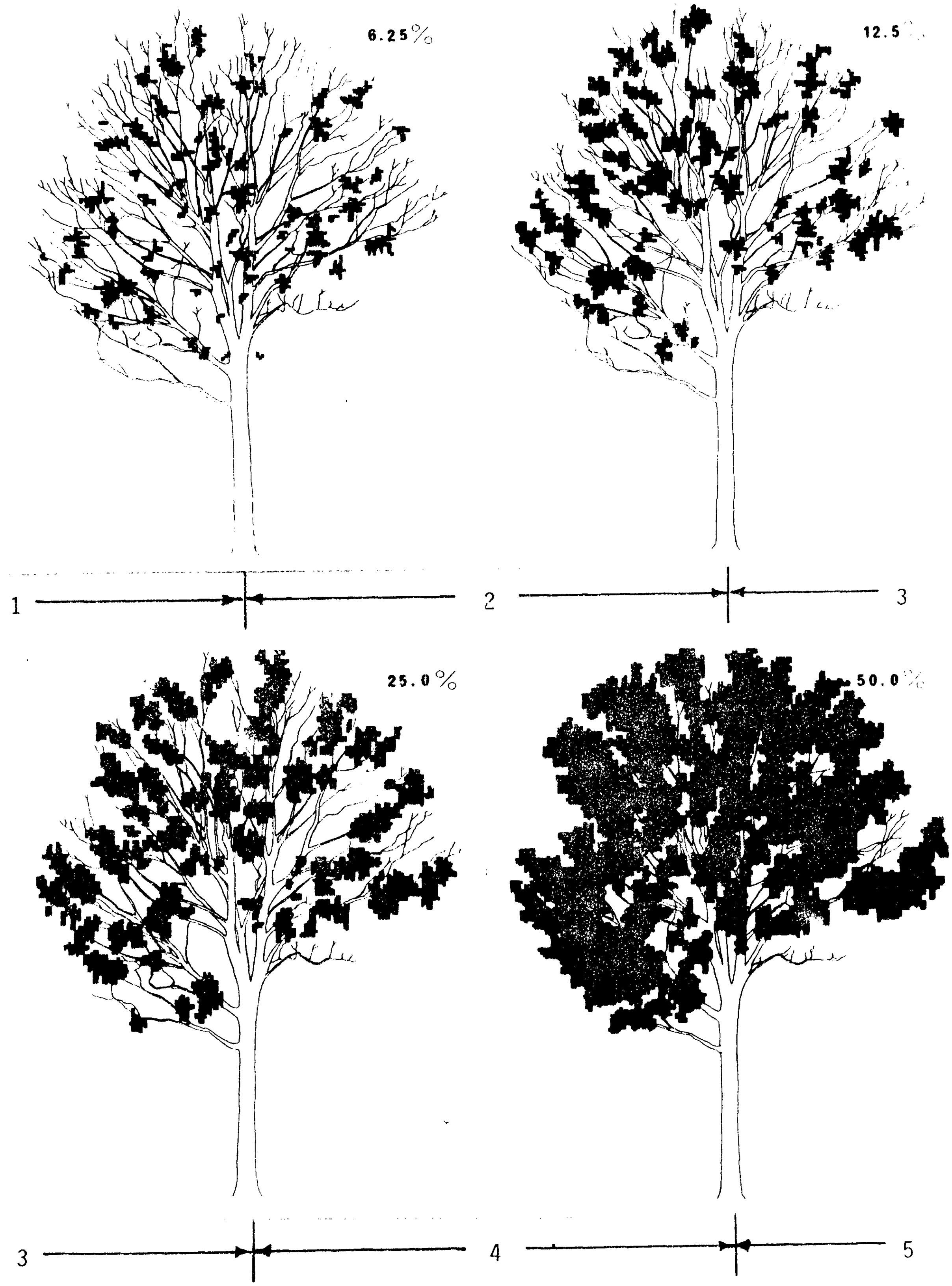


Figure 2.5.1 Projected foliage cover based on a perfect spherical canopy. Foliage cover classes are indicated by the arrows.

Use of the scale has limitations because tree crowns are 3-dimensional structures and not 2-dimensional silhouettes. Larger trees with the same foliage density as smaller trees will have a greater projected foliage cover. Hence only similar size classes can be strictly compared. In addition, viewing the tree from more than one direction is essential to minimize distortions due to irregular crowns.

(c) Assessment of saplings

The methods outlined above are of little value for the assessment of saplings. A scale based on the proportion of twigs which had died in the actively extending portion of the sapling's crown (see Table 2.5.2) was formulated. A set of photographs was also prepared to facilitate the estimation of leaf area (see Figs. 2.5.2 and 2.5.3). The leaf area of the sapling that was photographed was determined with a leaf-area planimeter.

2.6 Other tree characters.

Where appropriate other tree characters were recorded. These included: dominance status, size class, maturity class, visible deformities, evidence of structural damage, and presence of mistletoes. A list of the categories used to classify each tree with respect to each character is included in Appendix A.

(a)

(b)

(c)

(d)

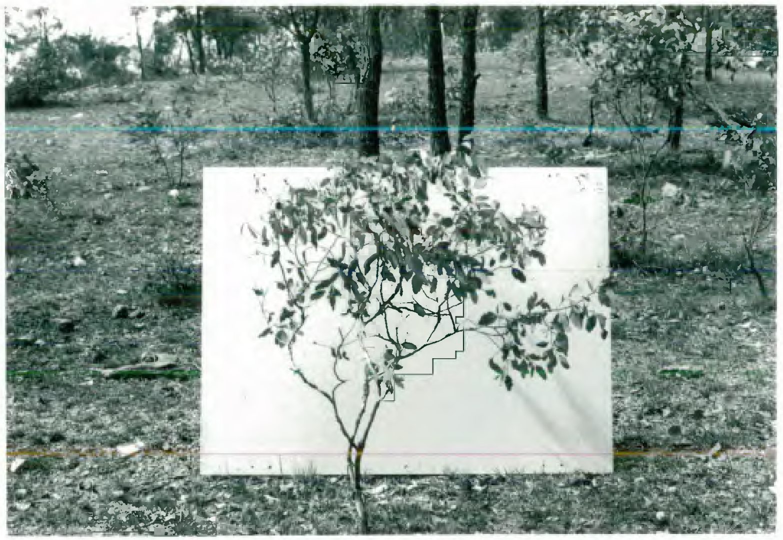


Figure 2.5.2 Photographic standards for assessment of the leaf area of saplings. The white backing board is 1 metre in height. (a) $0.094m^2$ of leaves; (b) $0.20m^2$; (c) $0.34m^2$; (d) $0.47m^2$. (Species: *Eucalyptus melliodora*; photos taken 13.2.81)

CHAPTER 3 THE PATTERN OF DIEBACK ON THE NORTHERN TABLELANDS

A broadscale survey was carried out to determine: which eucalypt species were most affected by dieback, the main areas involved, and other factors associated with the syndrome. The areas covered in the survey and principal study sites are shown in Fig. 3.0.1.

3.1 Description of the region.

For convenience the Northern Tablelands Statistical Subdivision will be used to define the region considered in the project (see Fig. 3.0.1.). In the east and south the escarpment forms a natural boundary to the Northern Tablelands, but the Dorrigo Plateau is excluded from the region. In the west there is a more gradual transition to the Western Slopes, with the Moonbi Range forming a natural boundary in the south-west. In the north the high country continues into Queensland and the state border defines the boundary of the region.

Relief. The altitude of much of the Northern Tablelands is over 1000 m, with the Guyra plateau and the Ebor area over 1200 m; there is a gradual decrease westwards, with Inverell at about 600 m. The Tablelands are sharply dissected in the east by gorge systems.

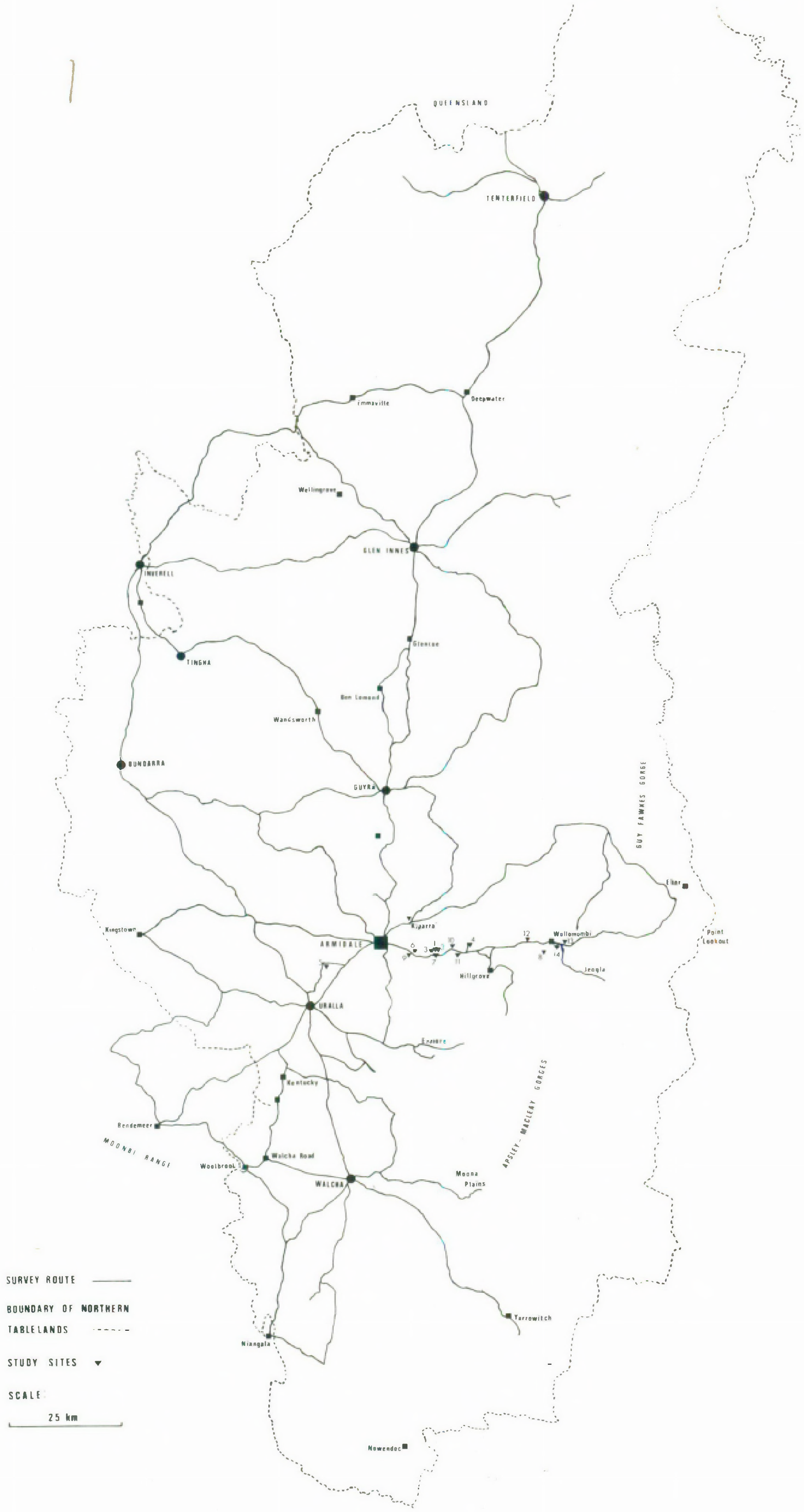


Figure 3.0.1 Areas covered in the road survey and principal study sites.

The topography typically forms gentle rolling country. However, broad relatively flat open plains and valley bottoms occur in some areas, and the remnants of granite outcrops are associated with some rugged terrain. There is a strong relationship between topography and the structural characteristics of the parent material (Swan, 1977).

Climate. Climatic factors vary greatly over the region. Mean rainfall is relatively uniformly distributed throughout the year with maxima in both summer and winter (see Section 8.1). Localized storms are responsible for a significant proportion of summer rainfall, and often contain hail. Average annual precipitation varies from about 2000 mm on some parts of the eastern scarp to about 750 mm in the Bundarra district. Snow seldom falls and rarely lasts for more than 2 or 3 days. Two prolonged and intense drought periods have occurred in the last 20 years. Frosts on the Tablelands are severe especially on lower lying parts of the high plateaus which are subject to cold air drainage. Wind storms are common in the region (see section 7.2) with west winds dominant and east winds common especially in the warmer months. The intensity of both frost and wind is affected by local topography.

Soils and parent material. Variations in parent material, topography, climate and history have led to the formation of a diversity of soil types in the region (Jessup, 1965; McGarity, 1977). Table 3.1.1 shows the great soil groups present in the region. Soils are chiefly derived from 3 types of parent

Table 3.1.1 Principle great soil groups on the Northern Tablelands.

Great soil group	Associated parent material
Krasnozem	basalt
Chocolate	basalt
Wiesenboden	basalt and other basic rocks
Prairie	basalt and basaltic colluvium
Black earth	basalt and basaltic colluvium
Euchrozem	basalt
Red podzolic	chiefly metamorphics, sometimes granites or basalts
Yellow podzolic	metamorphic rocks, various granites and porphyrys
Yellow earth	leucoadamellite
Gley podzolic	typically on granites
Yellow solodic	Paleozoic metamorphics, porphyrys, rhyolites
Grey-brown podzolic	granites

[Adapted from McGarity (1977), see Stace et al for a description of the great soil groups.]

restricted distribution.

materials (Voisey, 1963). The paleozoic basement consisting of greywackes, cherts, slates, phyllites, mudstones, volcanics and sandstones is especially common in the central tract of the Tablelands with other occurrences in the south and east. Tertiary basalt covers much of the high plateaus and forms the most fertile soils. The remaining area, including most of the rugged hills and dry sclerophyll forest, is covered by a heterogeneous group of granites. These granites vary markedly in their content of plant nutrient elements and give rise to contrasting soils: in general relatively fertile soils are derived from granites with a larger proportion of dark (ferromagnesian) minerals such as granodiorites, while infertile soils, often with poor profile development, are derived from parent materials such as leucoadamellite and porphyry.

Land use. A summary of land use statistics is presented in Table 3.1.2. Slightly over 75% of land in the Statistical Subdivision of the Northern Tablelands was alienated for agricultural purposes by 1979 (Dulley, 1979). In addition, significant areas are grazed under lease. Non-agricultural land predominantly consists of state forests, national parks and vacant crown land chiefly on the eastern edges of the Tablelands, including the gorges.

The pastoral industry dominates agricultural activity on the Northen Tablelands. During 1979 approximately 27% of grazing land was under sown grasses and clovers. Wheat and other field crops are grown in some western areas, particularly about

Inverell.

Areas least developed for agriculture or grazing generally have poor soils or a rugged terrain. Such areas include: dry sclerophyll forests on coarse granites, steep country surrounding the eastern gorges, and rugged granite and porphyry hills in the west.

3.2 The Vegetation

At present there is no comprehensive description of the vegetation of the Northern Tablelands. In 1904 Turner published an annotated list of vascular plants known from the region, while Cambage (1904, 1908) published field notes about plants encountered along two transects in western parts of the Tablelands. During the 1950s an extensive botanical survey was carried out by the CSIRO. A reasonably comprehensive species list with some ecological notes was written (Gray, 1963), but

Table 3.1.2 Land use in the Northern Tablelands

Total area	3 272 710 ha
Land alienated for agriculture	
Under sown grasses and clovers	666 192
Field and fodder crops	29 999
Orchards and vineyards	740
Other, including rangeland grazing	1 773 079
TOTAL	2 466 010 ha

Source: Dulley (1980)

only a preliminary characterization of the vegetation into types was attempted (Jessup, 1956). Baur (1962) described some of the vegetation types occurring in the region, concentrating on the eastern extremities. Williams (1963) wrote a generalized account of the vegetation, but excluded northern areas as well as areas in the extreme south of the Tablelands. Beadle's (1981) description of the Australian vegetation characterized the major vegetation alliances present in the region. Norton (1971a) wrote an account of the grasslands and woodland herb strata, while Whalley, Robinson and Taylor (1978) described the major natural pasture types present on the Tablelands.

The structure and composition of vegetation in any one place is determined by both the present and past environments as well as by the available flora (Jenny, 1958). Specific factors influencing the development of variations in the character of vegetation on the Northern Tablelands include variations of climate, topography, soil parent material (see Section 3.1) and human disturbance (see Section 3.3).

Before the arrival of European settlers the vegetation of most parts of the Northern Tablelands was dominated by eucalypts. Exceptions included: scattered pockets of cool temperate rainforest in protected areas immediately adjacent to the escarpment, patches of dry rainforest within the gorge systems (King, 1980), and bogs (Millington, 1954), fen and heathland mainly on poorly drained, low fertility soils in eastern parts of the Tablelands. Some natural treeless areas dominated by tussock grasses also occurred on heavy soils in broad valleys, e.g. on black clays near Glen Innes.

Eucalypt dominated communities ranged from tall open-forests and open-forests to a range of woodlands including savanna woodlands and shrubby woodlands. [The terminology used to describe vegetation basically follows Beadle and Costin (1952) with some modifications proposed by Specht (1970).]

The character of the vegetation has vastly changed due to agricultural development (see Section 3.3). Grassland or savanna woodland is now dominant in most areas utilized for pastoral production. The floristic composition of the understorey vegetation has been drastically altered by grazing and trampling, the introduction of exotic species, changes to the fire regime and, in many areas, the use of fertilizers and cultivation.

Tall Open-forests (wet sclerophyll forests). These forests are confined to areas of higher rainfall in the extreme east of the Tablelands and extend onto the escarpment. They are usually found on medium to high fertility soils, often derived from basalt, in sites protected from the extremes of weather: usually on slopes protected from the prevailing westerly winds and avoiding some cold-air drainage basins and flats. Trees are tall (30 to over 40m) with extended boles. The main tree species include: **Eucalyptus fastigata**, **E. obliqua**, **E. viminalis**, **E. laevopinea** and **E. andrewsii** ssp. **campanulata**. **E. nitens** has a limited distribution near Point Lookout and **E. saligna**, which is common on the escarpment, occasionally occurs in more protected forests on the Tablelands proper. Some of these species, particularly **E. obliqua** and **E. andrewsii** ssp. **campanulata**, also extend into open-forests.

In some areas there is a strongly developed understorey of mesomorphic shrubs, including rainforest plants. However, in most areas control burning practices have restricted such shrub development and only fire tolerant shrubs such as **Dicksonia** sp. and **Tasmannia stipitata** persist. The ecotone between tall open forest and cool-temperate rainforest (closed forest) may be either broad or narrow.

The ground layer is usually grass dominated, chiefly by **Poa sieberana**, or forb dominated (usually **Lomandra** spp.) and there is usually a scattering of inconspiicuous forbs. Ground ferns are often locally abundant.

Open-forests.

These forests are distinguished from tall open-forests by shorter trees (10-30m). They can be further subdivided into: (a) shrubby open-forests (dry sclerophyll forests) and (b) grassy open-forests. Forests within the Macleay Gorge system often have significant shrub development but for convenience are all included in the grassy open-forests.

(a) Shrubby open-forests (see Fig. 3.2.1) occur on low to medium fertility soils and are the dominant vegetation subform in eastern and south-eastern parts of the Northern Tablelands on soils derived from coarse granites, e.g. leucoadamelite. In

30a

Fig 3.2.1 Eucalyptus caliginosa - E. andrewsii ssp. **andrewsii** open-forest with an understorey dominated by **Acacia fimbriata** (about 10 km east of Emmaville, 2.10.80).

Fig 3.2.2 **Eucalyptus nova-anglica** woodland (about 8 km north of Niangla, 15.5.80).

some areas, such as south of Deepwater, these forests extend into the central tract of the Tablelands and there is a gradual transition from forests characteristic of the eastern parts of the Tablelands to open-forests more characteristic of the west. Open-forests with understoreys characterized by xeromorphic shrubs are also common on soils derived from porphyry and coarse granites in the west. Trees in some western forests are sparse and stunted with the structure of the community often bordering on a shrubby woodland.

Western shrubby open-forests are distinguished from the eastern forests by the absence of peppermints (except **E. andrewsii ssp. andrewsii**). Ironbarks and western red gums appear in many of the western forests. Examples of the range of eucalypts found in specific areas are listed in Table 3.2.1.

The vegetation is usually multilayered, especially in the east. Growth forms include: tall trees, small trees, shrubs, dwarf shrubs (chamaephytes) and herbs. Sometimes small trees and even larger shrubs may be absent. Information concerning the floristics of a representative plant community in a forest east of Wollomombi is presented in Beadle (1981). These open-forests in the east sometimes grade into shrubby woodland on more exposed sites with poorly developed soils; or into grassy open-forests where soils are more fertile and deeper. In sites with impeded drainage there is often a sharp transition to fen, bog or heathland.

(b) Grassy open-forests occur extensively throughout the

Table 3.2.1 Eucalyptus spp. occurring in open-forests characterized by xeromorphic shrubs (dry sclerophyll forest) on the Northern Tablelands.

Eastern

E. dalrympleana ssp. heptantha
E. radiata ssp. radiata
E. acaciiformis
E. caliginosa
E. youmanii
E. cameronii
E. pauciflora ssp. pauciflora
E. stellulata (rare, confined to lower slopes)
E. nova-anglica (lower slopes and valley floors)
E. andrewsii ssp. campanulata
E. andrewsii ssp. andrewsii (Gibralter Range only)
E. dives (extreme south only)
(less common species)
E. deanei
E. camphora (near Backwater)
E. quadrangulata (extreme south-east, rare)
E. oreades (Gibralter Range)

Central (south of Deepwater)
E. dalrympleana ssp. heptantha
E. bridgesiana ssp. bridgesiana
E. youmanii
(ecotonal)
E. blakelyi
E. melliodora

Western
(stringybarks)
E. caliginosa
E. laevopinea
E. mckieana
E. macrorhyncha
E. youmanii
(ironbarks)
E. caleyi
E. crebra
E. melanophloia
E. sideroxylon
(others)
E. albens
E. andrewsii ssp. andrewsii
E. banksii
E. nicholii
E. dealbata
E. bancroftii
Callitris endlicheri
(ecotonal)

E. blakelyi
E. melliodora
E. moluccana

Tablelands on soils of at least medium fertility. They are common in Tableland areas surrounding the Macleay gorges. Usually grassy open-forests are confined to slopes and ridgetops, but also may occur in other topographic positions when soils are well drained. In areas of the central tract of the Tablelands with podzolic soils there is often a regular toposequence of vegetation with grassy open-forests on the ridges and woodland on the slopes and valleys.

The ecotone between grassy open-forests and dry sclerophyll forest or woodland is often indistinct. Heavy grazing usually results in an increased proportion of grass cover at the expense of shrubs, while some unsuccessful attempts at clearing woodlands have resulted in vigorous regeneration converting the former woodlands to forest.

Grassy open-forests are usually dominated by stringybarks, though **E. andrewsii** ssp. **campanulata** is common in the east and **E. andrewsii** ssp. **andrewsii** is common in the west. Usually one particular species of stringybark is dominant in a specific area, but where more than one species is present hybrid swarms are common. Many eucalypt species found in other vegetation subforms extend into grassy open-forests, e.g. woodland trees such as **E. melliodora**, **E. blakelyi** and **E. conica** often occur in grassy open-forests (see Table 3.2.2).

A number of perennial grasses, e.g. **Aristida ramosa**, **Themeda australis** and **Poa sieberana**, are common in the understorey but often annual grasses are dominant and there is

Table 3.2.2 Eucalyptus species in grassy open forests surrounding the Maclaey Gorges.

E. cameronii
E. andrewsii ssp. campanulata
E. bauerana
E. michaeliana
E. viminalis
E. aff. cypellocarpa
E. saligna
E. melliodora
E. molluccana
E. amplifolia
E. tereticornis

Table 3.2.3 Eucalyptus species prominent in woodlands on the central tract of the Northern Tablelands.

(a) Usually above 1100m but occassionally at lower altitudes on cold sites; usually on soils derived from basalt. (hills)

E. pauciflora	
	E. viminalis
(lower slopes)	E. stellulata
(valley floors)	E. nova-anglica
(localized)	E. acaciiformis

(b) Independent of altitude; hilltops and other well drained situations.

(medium fertility soils such as podsolics)	
	E. caliginosa
	E. dalrympleana ssp. heptatha
(extends to richer soils)	
	E. laevopinea

(c)Usually below 1100m on soils of at least medium fertility.

(slopes)	E. melliodora
	E. blakelyi
	E. viminalis (on richer soils)
(slopes in wetter areas towards the east)	
	E. melliodora
	E. conica
(lower slopes towards the east)	
	E. amplifolia
(dominant in limited areas)	
	E. nicholii
	E. moluccana
	E. banksii
	Angophora floribunda
	A. subvelutina (northern areas)

(d) On broad plains and valley bottoms; above 900 m altitude.

	E. viminalis
	E. nova-angliça (extends to areas with impeded drainage)

little understorey vegetation after prolonged dry spells. Usually there are scattered shrubs and a diversity of forbs.

Woodlands in areas above 1100 m.

In the Ebor and Point Lookout areas the woodlands are mainly confined to the more fertile, basalt derived soils, but in contrast to the tall open-forests, generally occur on more exposed sites such as broad valleys and hilltops. Snowgum, **E. pauciflora** ssp. **pauciflora** is the dominant species; other trees include **E. stellulata** and **E.dalrympleana** ssp. heptantha. **E. pauciflora** shows some clinal variation, with smaller leaf sizes and a multiple-stemmed growth form in the higher areas such as Point Lookout.

The understorey is dominated by snowgrass, Poa sieberana, with a diversity of inconspicuous forbs and twiners. There are some scattered **Acacia melanoxylon** but few other small trees or shrubs.

There are also extensive tracts of subalpine woodland in other parts of the tablelands generally in areas above 1200 m altitude. These areas include the Guyra plateau, Moona plains and areas on the southern and south-eastern extremities of the Tablelands. Again the understorey is dominated by Poa sieberana tussocks and shrubs are sparse. There are relatively few species of shrubs or small trees, e.g. Acacia dealbata and Exocarpus cupressiformis on the Guyra plateau. Associations commonly occur in toposequences. A list of the principal eucalypt species occurring in subalpine woodlands is presented in Table 3.2.3.

Woodlands in areas below 1100 m.

With the exception of the high plateaus and the grassy open-forest areas most Tableland areas with soils derived from basalt, paleozoic sediments and fine granites were formerly covered by woodlands. The understorey was dominated by tussock grasses and the density of small trees and shrubs was probably generally sparse, but varied between localities with more prominent shrub development on less fertile or shallow soils. The woodland trees ranged in habit from tall straight trees almost 30 m tall to stunted trees barely 10 m high. Some species, e.g. **E. nova-anglica** (see Fig. 3.2.2) and **E. viminalis** occurred in both forms.

Table 3.2.4 describes the eucalypts occurring in woodlands on the central tract of the Northern Tablelands. The **E. melliodora -E. blakelyi** alliance dominates much of the stretch of country between Walcha and the Guyra plateau as well as many areas north of Glen Innes. This alliance extends onto the western edge of the Tablelands where **E. melliodora -E. blakelyi** associations intergrade with associations dominated by **E. albens**, **E. moluccana** and **Angophora floribunda** (see Table 3.2.5). In addition, **Brachychiton populneus** is present in some areas.

In many areas, especially east of the Divide, **E. caliginosa** associations and **E. melliodora -E. blakelyi** associations are intermingled with the stringybarks favouring the more elevated

Table 3.2.4 *Eucalyptus* species prominent in woodlands in western parts of the Northern Tablelands.

Mid to lower slopes and flats on soil types ranging from euchrozems to soils derived from coarse granite contain combinations of the following eucalypts:

E. melliodora	*E. albens* (extends to hillslopes)
E. blakelyi	*E. bridgesiana* ssp. *bridgesiana*
Angophora floribunda	

River banks:
E. camaldulensis

Bendemeer locality - mid to upper slopes:
E. mannifera ssp. *elliptica*
E. bridgesiana ssp. *malacoxylon*

N.B. Other eucalypts in open-forests often extend into woodlands (see Tables 3.2.1, 3.2.2).

positions. The dynamic nature of the ecotone between forests and woodlands has already been mentioned.

Two related eucalypts **E. viminalis** and **E. nova-anglica** both often occur in monospecific associations which cover extensive areas on the Northern Tablelands. In addition hybrid swarms of the 2 species (formerly named **E. huberana**) occur in many areas. **E.nova-anglica** has a well defined range which is sharply truncated towards the west.

3.3 Historical Background

Until the early nineteenth century the Northern Tablelands were exclusively the domain of Aboriginals. Considerable evidence is accumulating which indicates that fire regimes imposed by aboriginal populations were important in the maintenance of vegetation character over large parts of Australia (Gill et al, 1981; Smith, 1982). Frequent burning off to reduce regrowth of scrub as well as "fire-stick farming", ie. selective use of fire to favour food plants and regulate the movements of game animals, undoubtably took place on the Northern Tablelands.

Evidence suggests that aboriginal tribes from the coast and Western Slopes ventured onto the Northern Tablelands during certain seasons but probably only one tribe occupied the actual Tablelands on a permanent basis (Belshaw, 1966; Bowdler and Coleman, 1981). Unfortunately, the sudden disruption of aboriginal life due to conflict with the first European settlers

(Blomfield, 1981) has prevented a full understanding of the manner in which aboriginals influenced the physical environment.

Occupation of the Northern Tablelands by pioneer squatters began in the 1830s and the pastoral industry was well established by the 1850s. Early reports describe the Tablelands as lightly timbered with some naturally occurring treeless areas, such as Salisbury Plains south of Uralla, though on ridges there was a higher stand density (Walker, 1963; Norton, 1971). There was no mention of unusual tree decline by any of the early explorers. However, the first European explorer, Oxley (1820) made reference to an unusual amount of fallen, dead timber. He suggested that Aboriginals burning trees in order to remove possums may have been responsible for much of this dead wood.

During the first part of the nineteenth century land tenure arrangements were generally insecure. Consequently there was little investment in agricultural improvements. The runs were usually unfenced and flocks were attended by shepherds. The situation changed after the Robertson Land Acts of 1861. These acts were designed to encourage closer settlement. The selections were too small for total reliance on grazing. Nevertheless, many pastoralists acquired adjacent selections through "dummy landholders" who claimed the selections on their behalf. Thus the region eventually became dominated by extensive grazing properties (Walker, 1966).

Travelling stock routes became well established soon after the Roberson Land Acts. The land was portioned off relatively quickly and little unalienated land remained by the 1880s. Extensive fencing replaced shepherds during the closing decades of the nineteenth century. Clearing, drainage of swamps and other improvements were attempted. Woody regeneration became a problem in the absence of grass fires which had previously been common as a result of Aboriginal activities. Regrowth was especially a problem where trees had been cleared. Burning of paddocks in early spring was adopted as a regular practice in order to control woody regrowth as well as to stimulate fresh pasture growth. Progressive clearing continued, usually by ringbarking and woody regrowth remained a problem. According to Norton (1971) by the end of the century, the "character of the Tableland vegetation had changed from a park-like grassland to a mixture of dense woodland and savannah".

From the middle of the nineteenth century onwards there was concern regarding the "decadence" of Australian native vegetation. This stimulated a long running essay competition on the subject by the Royal Society of New South Wales. Localized occurrences of dieback were reported in several parts of the country in these essays. These essays stimulated Norton (1886) to report that in the 1850s near Walcha "on several hundred acres the whole of the peppermint trees (E. nova anglica) died away completely". A few years later several thousand acres of trees died in a similar manner. Subsequently there was a general lack of vitality in several kinds of trees particularly white gums (probably **E. viminalis**). Norton (1886) associated this declining tree vigour with sudden fluctuations in water availability in combination with stock compacting soil by trampling. Isolated reports of unusual tree decline continued into the twentieth century (Boyd, 1965).

Livestock numbers continued to rise reaching a peak before 1910 when further expansion was limited by the available pasture (McDonald, 1968). The practice of burning off pastures each year was largely discontinued during the 1930s. Though attempts to introduce exotic pasture plants began in the nineteenth century, during the 1950s aerial spreading of superphosphate and clover seed commenced on a large scale (Wright, 1964). Native pastures were progressively replaced and many areas were cultivated and sown with introduced grasses. Stocking rates increased dramatically. In 1946 the average stocking rate was 2.2 dry sheep per hectare; by 1966 this had risen to 3.6 dry sheep per hectare, and on some properties, the stocking rate had increased to 8.2 sheep per hectare (McDonald, 1968). Regrowth, which had previously been a problem, requiring farmers to return to the area repeatedly to suckerbash seedlings and coppice, was now completely prevented by stock browsing (Clark, R.V. and D.W. Nicholson, unpublished).

There was some concern regarding increasing numbers of tree deaths in the 1950s (Anon., 1979). Prompted originally by A.W. Cameron of "Kalaya", Matheson (near Glen Innes), first the New England Rural Extension Committee (in 1962) and then the New England Rural Development Association (in 1964) began pressing for some official action to be taken regarding the problem (Boyd, 1965; N.D. Crew and R.A. Boyd, pers. comm.). Attention was also drawn to the problem of declining tree health in other areas. Pryor (1958) drew attention to the instability of parkland-like pastoral systems in which ageing trees were exposed to increased climatic stress and increased insect grazing pressure, and there was little chance of regeneration from new seedlings. Declining tree vigour over extensive areas continued and by the mid 1970s the large numbers of tree deaths had become an issue of concern.

Williams (Williams and Nadolny, 1981) noted three phases in the development of the current syndrome. In the first phase up to the 1960s, **E. nova-anglica** suffered chronic insect infestation and deaths occurred in a number of areas, e.g. along Saumarez Creek west of Armidale between 1949-52 (T. Edmonds, pers. comm.). There were a few reports of dieback of other species, e.g. localized mortality of **E. melliodora** was noted on the Salisbury plains in the early 1950s (H. Croft, pers. comm.). By 1970, **E. nova-anglica** showed severe dieback in many areas and some dieback was evident in stands of **E. conica**, **E. melliodora** and **E. blakelyi**. The 1964-65 drought had affected a number of species, including **E. albens** and **E. macrorhyncha**, but most trees recovered (Hoult, 1970).

In the second phase, deterioration of **E. melliodora**, **E. blakelyi** and **E. conica** occurred over extensive areas and the deterioration of **E. nova-anglica** intensified. In the third phase, since about 1975, **E. viminalis**, **E. bridgesiana**, **Angophora** floribunda, E. caliginosa, E. stellulata and E. pauciflora also developed severe dieback in some localities, and minor occurrences of dieback were noted for some other species.

It may be helpful to consider the prevalence of dieback in terms of unfavourable alterations to the trees' environment. Historical developments which may have resulted in these alterations include: the introduction of stock; clearing; pasture improvement; increased mechanical and chemical disturbance; over-liberal use of fire followed by its total abandonment; and destruction of wildlife and native vegetation. Periods of severe climatic stress, or general climatic changes may also be of importance. The possibility that new disease agents have been introduced also requires discussion.

3.4 Other studies attempting to delineate the extent of dieback

Subsequent to Hoult's (1970) study concerning the effects of drought on trees (see Section 8.1) and prior to the commencement of this study, there were two significant attempts to gather information relating the occurrence of dieback on the Northern Tablelands with site and tree factors. Two further studies were initiated concurrently with this project.

In the first study the NSW Forestry Commission (R.V. Clark and D.W. Nicholson, unpublished data; Mackay, 1978, Clark et al., 1981) conducted a survey in 1977 which entailed broadscale reconnaissance of areas affected, gathering information from farmers, and compilation of tree data from field plots.

A road survey covering most of the New England region extending to the western plains was carried out. Dieback was found to be generally confined to elevations about 800 m on the Tablelands with the affected country stretching from south of Walcha to Tenterfield.

Thirty field plots were chosen by dividing a 5000 sq km area encompassing Guyra, Armidale and Walcha into 15 rectangular subregions and choosing two plots from a randomly selected property in each subregion. There were 680 trees (594 still alive) contained in these plots. The design offered little provision to ensure that there would be sufficient replication of all site and tree characters to enable a full statistical comparison, but the study was sufficiently broad to provide an indication of the situation.

Assessment of dieback severity was based on a determination of defoliation (see Section 2.3). This measure was justified in a follow up study in 1979 which discovered a strong association between high defoliation scores and mortality rates.

The predominant plot species was found to be the most important site factor associated with severe defoliation, with stands showing greatest defoliation usually dominated by E. nova-anglica and E. blakelyi. The preliminary analysis also indicated that position on slope, poor drainage conditions and absence of understorey shrubs were also associated with high defoliation scores, however these factors were all associated with predominance of **E. nova-anglica** and **E. blakelyi** and their significance is questionable. Trees on lower slopes were most defoliated, trees on mid slopes least defoliated with trees on ridges intermediate. There were no strong trends associated with geology or stand density. While dominant trees in dense stands were generally less defoliated than woodland trees, suppressed trees in the same stands were generally more defoliated than the woodland trees. Less than 2% of the 680 trees in the plots were classed overmature, so natural senescence could be disregarded as an important factor in the syndrome. Among other age classes saplings (46.5% defoliation) and immature trees (42.5% defoliation) were more defoliated than mature trees (36.8% defoliation).

The second study (Cross, 1979) incorporated Duggin's (1981) thesis that the Northern Tablelands is sufficiently heterogeneous to warrent subdivision into ecological provinces. Hence attention was focused on a small area (2400 HA) and 1134 trees in 40 plots were assessed.

Species association, slope, stand basal area and tree density were all correlated with severity of dieback ($P < 0.01$), while there were no significant effects due to aspect, soil type, topographic position or parent material. (Only 2 types of parent material, basalt and adamellite, were present). Again woodlands dominated by **E. blakelyi** and **E. nova-anglica** had most severe dieback, but slopes less than 8 degrees and low stand densities (or low basal areas) were also correlated with severe dieback.

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